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There is then every indication that further study will show that the colors of crabs and their capacity to change them vary from species to species according to the same general rules that appear to prevail among fishes.³ But if in two groups of animals so widely separated the same laws of coloration prevail, and if the observed facts point so unanimously to the concealing function of coloration in each, it becomes increasingly improbable that other laws prevail as extensively as has been supposed among other animals, and increasingly evident that adaptation of the organism to its environment is one of the most striking of natural phenomena.

¹ Darwin, C., *Descent of Man*, Chap. 9.

² Cowles, R. P., *Washington, Carnegie Inst., Pub.*, No. 103, 1908, (1-41).

³ Longley, W. H., *J. Exp. Zool., Wistar Inst. Philadelphia*, 23, 1917, (536-601).

THE EQUILIBRIUM OF TORTUGAS SEA WATER WITH CALCITE AND ARAGONITE

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The question of the solubility of calcite and aragonite in sea water is a matter of interest in relation to the geology of limestone and dolomite. Murray and Hjort¹ maintain that sea water is so complicated a mixture that the solubility of CaCO_3 cannot be calculated with certainty (from the law of mass action) but that the experiments of Anderson and of Cohen and Rahen show that sea water is saturated with calcite. They add, (p. 181) that dolomite is less soluble than calcite in carbonated waters. Their book summarizes observations showing that calcium carbonate is precipitated in shallow tropical waters, but that even shells are dissolved in the red clay bottoms of the depths.

Mayer² placed pieces of *Cassia* shell in sea water for more than a year and found them to maintain their weight within about $\frac{1}{10}$ of 1%. The precipitation of CaCO_3 at Tortugas was studied by T. Wayland Vaughan, R. B. Dole, and G. H. Drew.³ Drew observed that a denitrifying bacillus, *Pseudomonas calcis*, obtained from the sea water, was capable of changing calcium nitrate to calcium carbonate in culture media and supposes a similar process to occur in sea water. Since Vaughan has observed that calcium carbonate is constantly precipitating at Tortugas, Drew's hypothesis necessitates the presence of an appreciable amount of nitrates or nitrites, and I have attempted to determine them.

A half liter of sea water was boiled in an all-glass still and the distillate collected in a series of 25 cc. Nessler's tubes. Another series of Nessler's tubes were filled with a graded series of concentrations of ammonium chloride. One cubic centimeter of Nessler's reagent was added to each tube and agitated. After fifteen minutes, the tubes were compared colorimetrically and the ammonia recovered from the sea water was estimated. After no more ammonia could be distilled from the sea water, amalgamated aluminium shavings were introduced into the still and the distillation process repeated. The ammonia recovered was formed by reduction of nitrates and nitrites. Duplicate analyses gave less than 0.01 mgm. of nitrogen per liter as ammonia and less than 0.01 mgm. nitrogen per liter as nitrates and nitrites. Raben found more than ten times these quantities in North Sea water.⁴ Evidently, *Pseudomonas calcis* and other organisms have almost completely removed the fixed nitrogen from Tortugas sea water. The effect of this probably explains the scarcity of life in the vicinity of Tortugas as compared with colder seas (law of minimum). There is, however, a constant renewal of fixed nitrogen from the atmosphere, from the decay of organisms and probably from water rising from the depths of the ocean. If *Pseudomonas calcis* is an important agent in the precipitation of CaCO_3 , its action is evidently more intense in places where calcium salts, nitrates and nitrites are carried from the land into the sea.

That calcium carbonate is withdrawn from surface waters of the sea, is shown by chemical analyses. Dittmar⁵ found an average of 0.44% less calcium in surface waters than in deeper waters. This is true notwithstanding the fact that calcium carbonate is constantly being added to the surface waters. The drainage of the land contains an excess of calcium carbonate and flows out on the surface of the sea, where the water evaporates leaving the excess of CaCO_3 in the sea water. The action of organisms in building calcareous structures may account for a large part of the depletion of surface waters, but the precipitation of calcareous mud at Tortugas has been observed by Vaughan.

The analysis of the calcium content of sea water requires double precipitation, and filtration for separation from magnesium and hence large samples and great care are required for accuracy. Theoretically, however, we may detect differences in calcium content by titration. Dittmar showed that except for H_2O , calcium and gases, sea water is remarkably constant in composition. The water content may be determined by titration of the chlorides and the gases may be eliminated by boiling after the addition of enough acid to decompose the carbonates. If we disregard carbonic acid, there is an excess of bases

in sea water, i.e., the sum of the base equivalents is greater than the sum of acid equivalents. Since calcium is added to or taken from sea water in the form of CaCO_3 , and change in the calcium content causes an equivalent change in the excess base or alkaline reserve, as it is called by chemists. The alkaline reserve may be titrated while boiling the sea water to eliminate CO_2 . The exact value of the titration depends on the indicator used and the exact color of the indicator that is taken as the end point, hence only those titrations done in the same manner can be strictly compared. The titrations, used for the present paper were made by adding di-brom-o-cresol-sulphone-phthalein to 100 cc. of sea water in a flask of resistance glass and titrating with 0.01 N HCl , while boiling, until the purple color changed to yellow and did not become purple again after boiling for 5 minutes longer. The sides of the flask must not be allowed to dry as this would cause HCl to escape from the chlorides, due to the action of Magnesium. The results per liter were recorded and some titrations were made at 20° and others at 30° , but the errors due to change in volume of the sea water is within the limits of accuracy of the method. If the sea water is diluted with rain water, the alkaline reserve will be lowered, but this error may be compensated by dividing by the chlorine content (grams chlorine per kilogram sea water). In other words: a change in the quotient of the alkaline reserve by the chlorine per cent indicates a gain or loss of CaCO_3 .

	ALKALINE RE- SERVE	Cl %	$\frac{\text{Alk. res.}}{\text{Cl \%}} \times 10,000$
Sea water from San Diego, Cal.....	0.00235	18.7	1.257
Sea water from Woods Hole, Mass.....	0.00240	17.7	1.356
Gulf Stream, off Miami, Fla.....	0.00250	19.9	1.257
Gulf Stream, off Tortugas, Fla.....	0.00250	19.9	1.257
Average, Tortugas, June and July.....	0.00247	20.0	1.235
Average, Key West, June and July.....	0.00237	20.0	1.185

The above table indicates that some CaCO_3 has been removed from Tortugas sea water, as compared with other sea water, and to a greater extent from Key West sea water. In other words, the precipitation observed by Vaughan is not due to a greater amount of calcium in Tortugas or Key West sea water but to local conditions which cause the precipitate to form.

According to the law of mass action, in a saturated solution of CaCO_3 in sea water at constant temperature, salinity, etc.,

$$[\text{Ca}^{++}] \times [\text{CO}_3^{--}] = \text{a constant.}$$

Not all of the calcium is, however, in the form of CaCO_3 and Ca^{++} , for some is undissociated CaCl_2 , CaSO_4 , $\text{Ca}(\text{OH})_2$, and CaHCO_3 . The chlorides and sulphates are constant but $[\text{CaHCO}_3]$ and $[\text{Ca}(\text{OH})_2]$ change with the total CO_2 content of the sea water. But I have shown⁶ that if the alkaline reserve remains constant, the total CO_2 of sea water (within limits found in nature) varies inversely with the pH ($= -\log \text{H}^+$ concentration). Hence the determination of the pH may be substituted for that of the total CO_2 . The determinations I have made of the water of the Pacific and North Atlantic showed the pH to vary from about 8.1 to 8.25 and those of Dr. A. G. Mayer in the Pacific showed only a little wider range (below 8). Earlier observations at Tortugas gave the same range, but my more extended observations made this summer demonstrate the inadequacy of a few determinations. The pH is influenced by plant and animal life and rises at Tortugas to 8.35 during the day over well-lighted bottoms rich in vegetation, and falls to 8.18 during the night. It may be said, therefore, that conditions in shallow water over eel-grass or other sea-weed or corals (with symbiotic algae) favor the precipitation of CaCO_3 .⁷

The question arises whether the occasional high pH of Tortugas sea water is sufficient to explain the precipitation of CaCO_3 , or whether nuclei for the separation of the solid phase are necessary. A large amount of CaCl_2 may be added to sea water without causing a precipitation. If the pH is increased by the addition of NaOH, the result depends on the speed at which the alkali is added. If the NaOH is added suddenly in the form of a strong solution, colloidal precipitation membranes form about the drops and if the membranes are broken by shaking or stirring, a great mass of $\text{Mg}(\text{OH})_2$ is included in the precipitate. If a very dilute solution of NaOH is added very slowly, CaCO_3 possibly contaminated with $\text{Mg}(\text{OH})_2$, is precipitated. The exact pH at which precipitation first occurs cannot be determined by this method as the first precipitation occurs before the solutions are mixed and the crystals thus formed serve as nuclei for further precipitation. If Tortugas sea water is kept in glass bottles, precipitation occurs on the glass while the pH of the water is within the natural limits, but the pH at the glass surface is higher, due to solution of glass.

Although the pH at which precipitation would occur without nuclei for the separation of the solid phase, may be practically impossible to determine, the final equilibrium with an abundance of nuclei is not a difficult problem. Calcite and aragonite crystals to serve as nuclei were produced by the methods of Johnston, Merwin and Williamson.⁸ The crystals were examined under the microscope and tested with cobalt

nitrate solution. These observations, together with the mode of preparation, leave little doubt that the crystals actually were calcite and aragonite. Under the microscope an occasional calcite crystal could be found among the aragonite crystals but the number was not sufficient to affect the cobalt nitrate test. These calcite crystals apparently grew slightly during the experiments but apparently no new ones were formed. To determine the equilibria, crystals were mechanically stirred or shaken with sea water in 'nonsol' flasks, six to fourteen hours at 30°, then the pH and alkaline reserve determined.

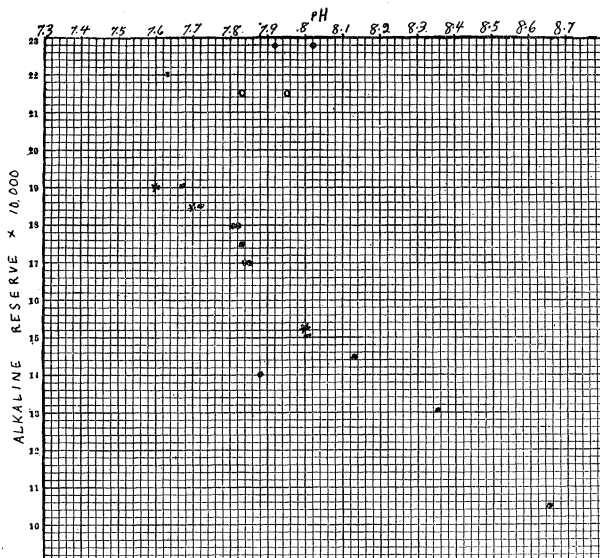


FIG. 1

The results are shown in figure 1. The alkaline reserve is measured on the ordinate and the pH on the abscissa. The results of agitating 100 grams of calcite crystals with a liter of sea water until equilibrium was approximately reached are shown by black rhombs in figure 1. If we draw a straight line from the intersection of the ordinates of pH 7.3 and alkaline reserve 0.0023 to pH 8.8 and alkaline reserve 0.0009, the determinations with calcite will fall very close to it. This shows that sea water of the surface of the oceans of the whole world is supersaturated in respect to calcite. We may therefore conclude that suitable nuclei for the precipitation of calcite are absent or deficient in number. The solubility of crystals varies inversely with their size, but after they have attained sufficient size to be readily examined with low powers of the microscope, further increase has an unappreciable effect on solubility. But such crystals if present, would be rapidly precipitated to the bot-

tom of the sea, hence the absence of nuclei for precipitation of calcite is what one might expect.

Aragonite is said to be about 10% more soluble than calcite, but no difference in the point of equilibrium of the two substances with sea water was detected in these experiments. This may be explained by the facts that a few calcite crystals were mixed with the aragonite, equilibrium was only approximated and there were slight errors in the determinations. The results are shown by black rosettes in figure 1.

During the rough weather, white calcareous mud is stirred with the sea water at Key West and to a lesser extent at Tortugas, and it was thought possible that the mud granules might form nuclei for precipitation and explain the low alkaline reserve at Tortugas and lower alkaline reserve at Key West. On agitating white calcareous mud, dredged from the bottom, with sea water, no definite equilibrium was reached, even at the end of four days. If the alkaline reserve was first lowered by removal of some CaCO_3 , it remained lower than if shaken with calcite and if normal sea water was used the alkaline reserve remained higher than with calcite. It was thought possible that the grains were covered with an impenetrable film of organic matter; so some mud was dried and powdered in a mortar in order to break the pieces and form fresh surfaces, but similar results were obtained with this. The results are shown by black circles in figure 1.

If mud was mixed with an equal weight of calcite, the results were the same as with pure calcite, as shown by the black dumb-bells in figure 1. This mud and calcite on standing in sea water for thirty days had not changed to calcite. All these facts tend to show that the particles in the mud are in some way retarded or prevented from getting into equilibrium with the water.

In order to be sure of clean surfaces of natural calcareous substances, a specimen of coral, *Maeandra clivosa*, was ground and powdered in a mortar and agitated with sea water in the same manner as in previous experiments. The results were similar to those with mud, as shown by the white circles in figure 1.

There seems to be a more soluble form of calcium carbonate (the μ CaCO_3 of Johnston), but since it cannot be obtained in a pure state, no attempt was made to prepare it. One experiment, however, was made with a precipitate of CaCO_3 that appeared as spherical grains under the microscope. It was agitated for twelve hours with sea water and the alkaline reserve was 0.0022 at pH 7.95. No further experiments were made to determine whether equilibrium had been approximated.

These experiments clearly show that the surface water of the sea is a supersaturated solution of CaCO_3 and it is only necessary to introduce calcite crystals in order to cause considerable precipitation of this substance. Precipitation goes on in the bodies of organisms in the surface waters of all seas. The precipitation observed by Vaughan at Tortugas is very finely divided, but whether it was formed in the bodies of minute organisms, which subsequently died, has not been determined. Such particles might slowly grow, since the agitation of them with sea water was found to take a trace of CaCO_3 out of the water. Small crystals have been seen in the bodies of Protista, and whether they are CaCO_3 or not, they might form nuclei for the precipitation of CaCO_3 if released into the sea water.

In some experiments in liter flasks of resistance glass, filled into the neck (and hence admitting of but slight loss of CO_2) the pH and alkaline reserve was determined immediately before and after agitation with calcite, and the loss of CO_2 from the sea water calculated from the pH and from the loss of CaCO_3 (alkaline reserve).

SEA WATER	pH	TOTAL CO_2	ALKALINE RESERVE	CALCULATED LOSS OF CO_2	
				From pH	From alk. res.
Before agitation with calcite.....	8.2	44.5	0.0025	6	6.72
After agitation with calcite.....	7.67	38.5	0.0019		
Before agitation with calcite.....	8.25	43.8	0.00250	6.8	7.27
After agitation with calcite.....	7.72	37.0	0.00185		

In the above table, the agreement is very striking in view of the probable error in determination of pH and the liability to loss of CO_2 from the water surface in the neck of the flask, agitated by the rotary stirrer.

If the pH of sea water should be maintained (by the action of plants) at 8.2 while it was agitated with calcite crystals, the loss of CaCO_3 would be about 0.001 N, or 0.0005 M, or 0.1 gram per liter. This would cause a deposit of 10 kgm. per square meter of bottom in water 100 meters deep. This would cause a lowering of the calcium content of Tortugas sea water by about 4.5%.

¹ *The Depths of the Ocean*, London, 1912, p. 178.

² These PROCEEDINGS, 2, 1916, (28).

³ *Washington, Carnegie Inst.*, Pub. No. 182, 1914, (Tortugas Lab., vol. 5).

⁴ *Depths of the Ocean*, p. 368.

⁵ *Voyage of H. M. S. Challenger, Physics and Chemistry*, vol. 1.

⁶ McCleendon, *J. Biol. Chem.*, Aug., 1917.

⁷ It would be interesting to know whether corals and calcareous algae deposit as much CaCO_3 in the dark as in the light. Corals from deep water are smaller, more fragile, and deposit less CaCO_3 than those of shallow water, but the same is true of animals without symbiotic algae. The deposition is, however, related to the pH, since Palitzsch has shown that the pH decreases with depth.

⁸ *Amer. J. Sci., New Haven*, **41**, 1916, (473).

AN OENOTHERA-LIKE CASE IN DROSOPHILA

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Although the large bulk of the *Drosophila* work has been remarkably self-consistent, and amenable to orderly and definite rules of factor transmission, yet from the outset the ideal scheme has been confronted with two unconformable cases. These are the cases of beaded wings and of truncate wings, both of which seemed to belie the idea of clear cut segregating gens. In the case of beaded wings, which will be briefly reported here,¹ many generations of selection were carried out by Morgan with the purpose of obtaining a pure breeding stock, yet for several years it was impossible to attain this object. The character showed all the peculiarities which would be expected as a result of factor fluctuation and miscibility. It was increased in intensity as a result of selection yet its essential variability remained, and the latter was proved by crosses to be genetic, for Morgan found that reversed selection produced a marked and immediate retrogression in the proportion of beaded thrown. Finally, however, he did obtain a race which threw no normals, but the reason for this change in behavior seemed now just as difficult to discover as the cause of the previous variability. On crossing, various apparently irregular results and aberrant ratios followed.

The work of Dexter, which showed that environmental conditions and factors in both the second and third chromosomes are all concerned in the development of this character, provided valuable information for the present investigation. Starting from Dexter's finding that there was a chief factor for beaded in chromosome III² an attempt was made by the writer to find the precise location of this gen. It proved to lie at the extreme right hand end of the known factors in the third chromosome, being two and a half units beyond the factor for rough eyes, which is otherwise the furthest factor to the right. It was found also that the apparently pure beaded stock is not homozygous for beaded, but in reality contains two very different kinds of third chromosomes. It was by investigating this phenomenon, with the aid of the data secured in